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ABSTRACT

This paper summarizes a quantitative synthesis of studies of the effectiveness of interactive distance education using videoconferencing and telecommunications for K-12 academic achievement. Effect sizes for 19 experimental and quasi-experimental studies including 929 student participants were analyzed across sample characteristics, study methods, learning environment, learner attributes, and technological characteristics. The overall mean effect size was 0.147, a small positive effect in favor of distance education. Effect sizes were more positive for interactive distance education programs that combine an individualized approach with traditional classroom instruction. Programs including instruction delivered via telecommunications, enhancement of classroom learning, short duration, and small groups yielded larger effect sizes than programs using videoconferencing, primary instruction via distance, long duration, and large groups. Studies of distance education for all academic content areas except foreign language resulted in positive effect sizes. This synthesis supports the use of interactive distance education to complement, enhance, and expand education options, because distance education can be expected to result in achievement at least comparable to traditional instruction in most academic circumstances. A list of the studies is appended. (Contains 59 references.) (Author/AEF)

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The Effectiveness of Interactive Distance Education Technologies in K-12 Learning: A Meta-Analysis

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This paper summarizes a quantitative synthesis of studies of the effectiveness of interactive distance education using videoconferencing and telecommunications for K-12 academic achievement. Effect sizes for 19 experimental and quasi-experimental studies including 929 student participants were analyzed across sample characteristics, study methods, learning environment, learner attributes, and technological characteristics. The overall mean effect size was 0.147, a small positive effect in favor of distance education. Effect sizes were more positive for interactive distance education programs that combine an individualized approach with traditional classroom instruction. Programs including instruction delivered via telecommunications, enhancement of classroom learning, short duration, and small groups yielded larger effect sizes than programs using videoconferencing, primary instruction via distance, long duration, and large groups. Studies of distance education for all academic content areas except foreign language resulted in positive effect sizes. This synthesis supports the use of interactive distance education to complement, enhance and expand education options because distance education can be expected to result in achievement at least comparable to traditional instruction in most academic circumstances.

Between 1989 and 1996, the number of instructional computers in schools increased over 200% and by 1997, the number of schools with Internet access had reached 70% (Software Publishers Association, 1998). In today's education climate, use of current technology becomes

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increasingly critical in schools for several reasons. Schools that are able to demonstrate innovative educational strategies using technology are at a distinct advantage in attracting and keeping top students, and in earning further funding through grants, endowments, and programs. Of course, having technology does not ensure effective use of the tools, and therefore may not translate into education benefits. Schools are pressured by their communities to show that the investment is paying dividends in educational achievement. Educational administrators and decision-makers are challenged with providing increased educational opportunities without increased budgets. Many educators are responding to this challenge by developing distance learning projects.

As of 1995, 60% of all personal computers in K-12 schools were networked to another computer. Half of all school districts were using distance learning in the "business of education": academic modules and credit courses (CCA Consulting, 1996), driven by demand for time and place independence and by economic issues. Eighty two percent of the states reported that equality of educational experience in all schools was the principal need addressed by distance education projects that provide courses to homebound and remotely located learners (Quinn & Williams, 1987). Distance learning applies physical technology and education processes to serve the needs of students when they are removed from the source of instruction and resources by either time or distance. "As with most instructional tools, the purpose of distance learning is to help schools meet the instructional needs of their students and to enable students to access information more effectively and apply what they learn in school to the world in which they live" (ESA, 1995). Distance learning uses a group of systems to bring teaching and learning together by transmitting information or expertise from one place to another for learner benefit. Formally, distance education is characterized by physical separation of learners from the information, an

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organized instructional program, use of technological media, and two-way communication (Heinich, Molenda, & Russell, 1993).

The benefits of distance education as outlined by Kerka (1996) include flexibility to meet specific needs, providing equity of educational opportunity to students in varying localities, low-cost alternatives, new learning experiences, and expanded resources. Organizational learning forms infrastructures to enhance and extend the capabilities of the individual to collaborate and to utilize specialized knowledge of others (Molnar, 1997). All forms of education are enhanced by the increased access to information and communication afforded through distance education. Disadvantages of distance education include sound and video that may be less than broadcast quality, reliance on learner initiative to work in a situation with less supervision than a classroom, the need for technical skills to work with the delivery technology, and the possibility of social isolation (Kerka, 1996).

Distance acquisition of knowledge is often an expensive and time-consuming process to institute and maintain. It is important to know whether it actually improves student performance. It is also critically important to know which distance education delivery methods and techniques are more effective, so students get maximum benefit from society's investment in distance learning technology. Faced with so many new, rapidly changing options, schools need data in order to make quality decisions regarding distance education.

A review of distance education literature reveals well-developed theory supported by extensive experimental study. However, distance education research has not been subjected to repeated review and synthesis, especially in regards to K-12 education. Holmberg's theory of distance teaching (1985) states that distance teaching will support student motivation and promote learning pleasure and effectiveness if learners are engaged in discussions and decisions,

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and the program provides for real and simulated communication to and from the learners. As in any classroom, interaction is the core of teaching. Distance education is believed to work very well, and produce results as effective as traditional classroom instruction (Kearsley, 1996). However, the distance education currently in practice has the potential to provide more effective learning with updated pedagogy, more experience, and greater understanding and knowledge of methods. Numerous studies have evaluated student achievement in specific distance learning programs in higher education. According to Abrami and Buras (1996), learning at a distance is seldom superior to traditional instruction, particularly for promoting higher level achievement and complex skills. These weaknesses may stem from social and intellectual isolation. Improved distance education practices have the potential to enhance educational outcomes, especially when the amount and kind of learner interaction is increased using technology-supported collaborative learning.

Although distance learning is well documented with adults, fewer studies of effectiveness exist that center on the primary and secondary levels. At a point when all states offered distance education in schools, very few had conducted formal evaluations (Quinn & Williams, 1987). While it is possible that our knowledge of distance education technology in higher education is relevant with precollege learners, there is no empirical evidence for this assertion. Additionally, previous research has spread across grade levels, content areas, and technologies. Distance education program developers have paid less attention to the appropriate blend of media, content, learner, and gain; instead defining effectiveness in terms of the number of students served or student satisfaction (Eiserman & Williams, 1987).

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Purpose of the Meta-Analysis

In light of the lack of previous meta-analyses on the issue, the purpose of the current study was to arrive at a comprehensive assessment of the effectiveness of interactive distance education for K-12 learners. This meta-analysis had two main goals. The first goal was to determine the effects on K-12 student achievement of interactive distance education use of videoconferencing or on-line telecommunications. Traditional reviews of distance education literature conducted in the 1980's indicate that learners achieve as well in distance education programs as they do in traditional classroom settings (Moore, 1989). Other studies described by Moore and Thompson (1990) indicate that the instructional format itself has little effect on student achievement as long as the delivery technology is appropriate for the content, and timely teacher-to-student feedback is included. This research involved technology that is now outdated, and was not conducted using quantitative synthesis methods. Good distance teaching practices have been found to be fundamentally identical to good traditional teaching practices, with quality factors being universal across environments and populations (Wilkes & Burnham, 1991). This means not only that various studies of distance learning may be synthesized reliably, but that the results of such a synthesis ought to generalize to most comparable education situations. Meta-analyses have been performed recently to show trends correlating use of technology in general with improved achievement (Kulik, 1993; Ryan, 1994), but not focused on distance education.

The second main goal of this study was to identify the features (duration of use, frequency of use, instructional design, delivery system, ability of students, level of students, content area) of the most effective interactive distance education systems. The Software Publishers Association reported evidence that educational technology's positive effects depend on subject area, student

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population, and level of access to technology (1998). The present quantitative synthesis of studies is an effort to increase understanding of the effectiveness of distance learning on K-12 achievement by revealing the features and combinations of characteristics that make distance education most effective.

Method

Data Collection

Studies involving student academic achievement as a result of distance education at the K-12 level were assembled. Quasi-experimental studies were included with experimental studies because true experiments are done in artificial situations, while quasi-experiments usually occur in more realistic conditions. Quasi-experiments, although having lower internal validity, produce more realistic results and increased external validity (Carlberg et al, 1984). The setting for the studies is K-12 learning environments, with preference for studies using random sampling. Both published and unpublished studies are included to avoid publishing bias.

Studies were gathered from computer databases including ERIC, Dissertation Abstracts, requests from national and state distance education projects and the World Wide Web. Searches were systematically conducted in journals of education organizations (*American Journal of Distance Education, Journal of Educational Computing Research, Journal of Research on Computing in Education*) from the 1980's and 1990's because of the recent development of the distance education delivery systems being examined here. Searches employed the keywords

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"distance education", "distance learning", "teleconferencing", "videoconferencing", "satellite", "telecommunications", and "email". The technology directors for each state were contacted by email with requests for data. These initial searches unveiled references for hundreds of documents. Each document was located in ERIC files, on the Web, in journals, by interlibrary loan, or by ordering dissertations.

After examination, studies were included in the meta-analysis when they met all inclusion criteria: a focus on the use of interactive distance education technology for education at K-12 levels, either videoconferencing or on-line telecommunications; publication between 1980 and 1998; experimental or quasi-experimental design providing quantitative outcomes from which effect size can be estimated; freedom from obvious flaws. The bibliographies of studies that did not meet all inclusion criteria provided references for locating other studies. When studies lacked data for inclusion in this analysis, a direct request was made to the authors or sponsoring organization to send additional information. A total of 59 such requests were sent via post or email. A preliminary group of 59 studies was selected from all available studies for review to determine their appropriateness for inclusion in the meta-analysis. Of the 59 studies reviewed, 40 were eliminated for reasons including insufficient data on student achievement, failure to focus exclusively on K-12 learners, focus on attitude rather than achievement.

Coding and Interrater Agreement

Studies included in the meta-analysis were reviewed and coded independently by two doctoral students. The general categories of coding were publication characteristics, technological characteristics, ecological characteristics, methodological characteristics, and

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analytical results. Interrater agreement for all studies averaged 85%, and exceeded 80% for all categories of coding. In cases where agreement fell below 80%, the study was examined and the coding process was clarified. Percent agreement was calculated for each study by dividing the number of agreements by the total number of features coded, then multiplying by 100.

Classification of Variables

The dependent variable in this synthesis was student achievement in the academic content area measured by instruments appropriate to the individual study. The measure of student performance in the studies was indicated on achievement measures given at the end of the distance education period. Such measures included standardized tests and teacher/researcher designed instruments. Traditional measures may not be effective in assessing the effectiveness of distance education systems that strengthen higher order skills. Complex skills such as problem solving, motivation, writing, collaboration, and awareness of community are some of the benefits of using distance education (Pisapia & Perlman, 1992). Growth in these areas can only be inferred with the use of common achievement measures. The student performance measures used in the studies analyzed here are accepted as the best estimates of the effect of interactive distance education technology on student achievement currently available. Dependent measures were coded into one of eight content areas, one of three types of achievement measure, and one of four testing sequences. The content areas were general, language arts, mathematics, science, social studies, computer science, and foreign language. The types of achievement measure were standardized, teacher-developed, researcher-developed, and other (publisher-developed or final course grade). The testing sequences were pretest-posttest or posttest only.

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The treatment variables related to interactive distance education were categorized by duration, frequency, instructional design, and delivery system. Student characteristics including ability level and grade in school were also coded. Comparisons were made between distance education programs in which students used the technology for less than a half-year of instruction and those in which the technology was used for at least a half year. Programs exposing students to distance education activities almost daily were contrasted with programs in which students participated in distance education on a weekly basis. Within instructional design, studies were coded as either using distance education as the primary instructional delivery system, or as using distance education systems to supplement regular classroom instruction. The distance education delivery system was email, World Wide Web, or two-way audio-video conferencing. Student groups were coded on the grade level designations primary, intermediate, middle, or high school, and were classified as functioning at regular ability levels or advanced.

Effect Size Calculation

The achievement data reported in each study contributed to the calculation of effect size for the meta-analysis. Cohen's effect size is a standardized estimate of the difference in achievement between students learning with interactive distance education and students learning with traditional methods. Effect sizes were computed as the difference between the control and experimental posttest mean scores divided by the average standard deviation. For studies in which a group of students was evaluated using multiple achievement measures, effect sizes were found for each measure, and then averaged. The average effect size was used in the overall effect size estimate of the meta-analysis. For studies in which more than one independent group

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of students was evaluated, an independent effect size were found for each group and used in the meta-analysis separately. While different groups tested in one study were dependent with respect to study features and characteristics, the samples were independent. A correction factor based on Hedges, Shymansky, and Woodworth was applied to each biased effect size to remove bias by accounting for sample size (1989). The independent effect sizes were combined by weighted averaging to yield an overall effect size estimate.

Heterogeneity of effect sizes was estimated to determine the appropriateness of combining them into an average. A formal analysis of heterogeneity (ANOVA) was completed for the effect sizes with effect size as the dependent variable, and the study features as factors. The p-value for the ANOVA was also set at 0.01. This procedure enabled conclusions to be drawn regarding the significance of levels of variables. For example, the ANOVA may reveal that a certain level or type of learner achieves at significantly higher levels using a specific distance education system. In addition to the overall student performance, effect sizes were reported for each variable. Effect size comparisons were made with respect to the following variables: duration, frequency, instructional design, delivery system, ability level, grade level, and content area. Effect sizes were also compared for the study characteristics date of study, source of study, hardware components, achievement measure, and sample size.

Results

The 19 independent effect sizes calculated in this synthesis compared students learning with interactive distance education technology with students learning with traditional classroom instruction only. The weighted mean effect size across all studies was 0.147 (SD = .69). The

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mean sample size for the studies was 48.9 (SD = 13.2). The mean grade level of the students was 8.3, with a standard deviation of 0.59. The average study measured student achievement after 14.7 weeks of distance education (SD = 2.6). Studies using two-way audio-videoconferencing as the distance education system comprised 68% of the total, followed by 26% of studies that used email, and one study using the World Wide Web. The most common academic content area for the studies was science, with approximately 32% of the studies. All other content areas made up less than 16% each. All studies took place in school classroom environments. All studies except two involved regular level learners, and the remaining two studied advanced learners.

The average year of publication for the studies was 1993 (SD = .71), with dates ranging from 1986 to 1997. The most frequent source of studies was dissertations (68%), followed by journals (*Journal of Educational Computing Research, American Journal of Distance Education, Interactive Learning Environments*), and the World Wide Web. Approximately 84% of authors were affiliated with universities.

In terms of the experimental design, two-thirds of the studies used a quasi-experimental design, and one-third were experimental. Only 10% of the studies made use of random assignment to groups, while 53% used convenience groups such as school classes. The remaining studies grouped students based on other criteria such as volunteering or parent selection. A full 74% of studies employed a pretest-posttest design, and 36% used posttest only. The most common form of measurement instrument in the studies was researcher-developed tests (32%), followed by teacher-developed and standardized (26% each), and publisher-developed tests (16%).

Table 1.
Mean unbiased effect sizes by study variable

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Variable	Level	# of Studies	% of Total	Average Effect Size
Delivery System	Telecommunications	6	32	0.488
	Videoconferencing	13	68	-0.011
Duration	Over 15 weeks	8	42	0.094
	Less than 15 weeks	11	58	0.186
Frequency	Daily	13	68	-0.010
	Weekly	6	32	0.489
Instructional Design	Primary	13	68	-0.011
	Supplementary	6	32	0.489
Grade Level	9-12	13	68	-0.011
	3-8	6	32	0.489
Content Area	Science	6	32	0.069
	Social Studies	3	16	0.117
	Language Arts	3	16	0.432
	Foreign Language	3	16	-0.801
	Mathematics	2	11	0.758
	Other	2	11	0.811
Year	Pre-1993	8	42	0.225
	Post-1993	11	58	0.090
Achievement Measure	Standardized	5	26	0.279
	Non-Standardized	14	74	0.099
Test Sequence	Pretest-Posttest	14	74	0.295
	Posttest Only	5	26	-0.268
Sample Size	Fewer than 26	8	42	0.454
	Over 32	11	58	-0.076
Study Source	Published	6	32	0.590
	Unpublished	13	68	-0.057

For analysis, the effect sizes were classified into 12 categories related to features of the studies. Table 1 displays the mean unbiased effect sizes for these categories. Effect sizes above Cohen's threshold for "marginal" magnitude (below 0.45) occurred for studies of

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telecommunication, weekly use of distance education, use of distance education to supplement classroom instruction, mathematics and other subject areas (computer science and general elementary), and intermediate grade levels. Effect sizes above Cohen's 0.80 cutoff of "large" effect size were found only for the other subjects, and for foreign language in a negative direction. Seven studies in this synthesis had heterogeneity values above 5.3, indicating that they were "strikingly deviant". To further investigate the significant heterogeneity, analysis of variance of effect sizes was used. An ANOVA was computed for levels of variables shown in Table 1. Each ANOVA resulted in no significant difference between levels of the variables at the alpha level of 0.01. Even after the removal of the foreign language studies as outliers, the ANOVAs resulted in non-significant findings. The alpha values for the modified ANOVAs are presented in Table 2.

Table 2.
Modified ANOVA Results

Study Feature or Characteristic	ANOVA Alpha Value
Duration of Use of Distance Education	0.965
Frequency of Use of Distance Education	0.407
Instructional Design	0.406
Technology Delivery System	0.406
Student Grade Level	0.406
Content Area	0.437
Research Design	0.261
Study Date	0.776
Study Source	0.171

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Achievement Measure	0.387
Sample Size	0.129

The heterogeneity in the studies is unexplained. The optimal method for combining effect size estimates with unexplained heterogeneity is the random effects model (Hedges et al, 1989). Random effects procedures treat between-study variations in effect sizes as random. The procedures begin with the estimation of between-study variance, used to determine the difference between the observed variance among effect sizes and the within-study sampling variance. The sample variance for the 19 studies in the meta-analysis is 0.481. The between-study variance was found to be 0.413. This variance was used in calculating confidence limits and in combining the effect size estimates in the random effects model. The effect size formula was weighted with both the within-study sampling error variance (standard error) and the variance.

The overall effect size for the 19 studies is 0.147, considered a small positive result. The standard error of the effects weighted average is 0.159. This result is a small positive effect size. At an alpha level of 0.05, the 95% confidence limits were constructed by multiplying the square root of the variance, 0.413, by 1.96, then adding and subtracting from the effect size, d_+ (Cooper & Hedges, 1994). In this case, the confidence limits were -1.113 and 1.407. Because the interval encompasses zero, the null hypothesis that the population effect size is zero cannot be rejected. Interactive distance learning techniques cannot be considered to be more or less effective than traditional instruction.

Because of the near-significant result of the ANOVA for subject area and the cluster of outliers, a second overall effect size was estimated without the foreign language studies. The random effects effect size estimate for the meta-analysis was 0.344, discounting foreign language

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studies. The effect size improves after accounting for these discrepant studies in post hoc analysis, although the confidence interval of -0.686 to 1.374 still encompasses zero. The overall standard deviation for the random effects effect size estimate was found. The result for the 19 studies is a standard deviation for effect size of 0.480.

Discussion of Findings

The meta-analysis presented here examined a sample of studies that met established inclusion criteria, including data from 929 learners. The analysis encompassed a broad view of K-12 interactive distance education by focusing on the range of subject areas, grade levels, and applications of distance education in use today. The questions of the overall effect on K-12 academic achievement of interactive distance education, and of the features of effective distance education systems were addressed through the use of random effects effect size estimation and analysis of variance. The study design permitted review of a wide sample of research done on academic achievement of students learning with distance education.

The overall effect size for interactive distance education on K-12 learning was the small positive 0.147, accounting for sampling error and variance. The 95% confidence interval for the random effects weighted effect size was -1.113 to 1.407. In comparing levels of the variables delivery system, grade level, ability level, content area, instructional design, duration, and frequency of use, and the study features of date, source of study, achievement measure, testing sequence, and sample size, no significant differences were found. In a post hoc analysis after eliminating the outlier foreign language studies, an effect size of 0.344 was calculated, with a confidence interval of -0.686 to 1.374.

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As a result of the statistical processes applied in the meta-analysis, the overall effectiveness of interactive distance education has been estimated as it is used for K-12 learning. Interactive distance education was found to have an average effect size of 0.147, translating to a gain of 0.147 standard deviations on average for a student at the 50th percentile learning with distance education over traditional methods. No significant differences were detected between grade levels, subject areas, ability levels, distance education technology, duration and frequency of use of distance education, or instructional design in relation to learning. However, the three foreign language studies made a close approach to significance with strong negative effect sizes.

Consequently, distance education can be expected to result in achievement at least comparable to traditional instruction in most academic circumstances. Educators planning implementations of distance education programs should expect no difference in academic performance as a result of the use of distance education. More importantly, when implemented with the same care as effective face-to-face instruction, distance education programs can be used to complement, enhance and expand education options for students, at least at intermediate, middle, and upper grades levels.

Implications

In a time when standards-based education has taken on a greater real-world, situated focus, it has become more important for educators to provide students with authentic connections to a learning environment beyond the school boundaries. Interactive distance education is a vehicle for extending the reach of student influence into the community, as well as a means of including the family and community in a learning conversation. In light of the findings of this meta-analysis, supplementing traditional instruction with distance education can enable more reality-based learning, with possible achievement gains. The benefits of such educational

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enhancement in terms of attitude and interpersonal workplace skills are unknown at the present time.

Under pressure to present learners with greater opportunities at lower cost, educational leaders may find that offering courses to secondary learners via interactive distance education effectively enlarges the course catalog and students' worldview at the same time. On a cautionary note, distance education for K-12 is much newer and less proven than traditional instruction. The fact that only 19 studies were found to be suitable for this analysis is a testimony to that fact. Therefore, students and teachers have fewer quality materials and less experience on which to draw when using distance education. It can be argued that as the use of interactive distance education grows and expertise develops, academic gains can be expected to increase.

In the area of foreign language instruction, great potential exists theoretically for linking students with native speakers and writers, but the results of the studies reviewed here indicate that distance education in foreign language should be studied closely. The three foreign language studies in this meta-analysis reported that students learning with distance education systems performed demonstrably lower than students learning in traditional classrooms. While foreign language options are needed in high schools, distance education courses for foreign language instruction should be evaluated very carefully.

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